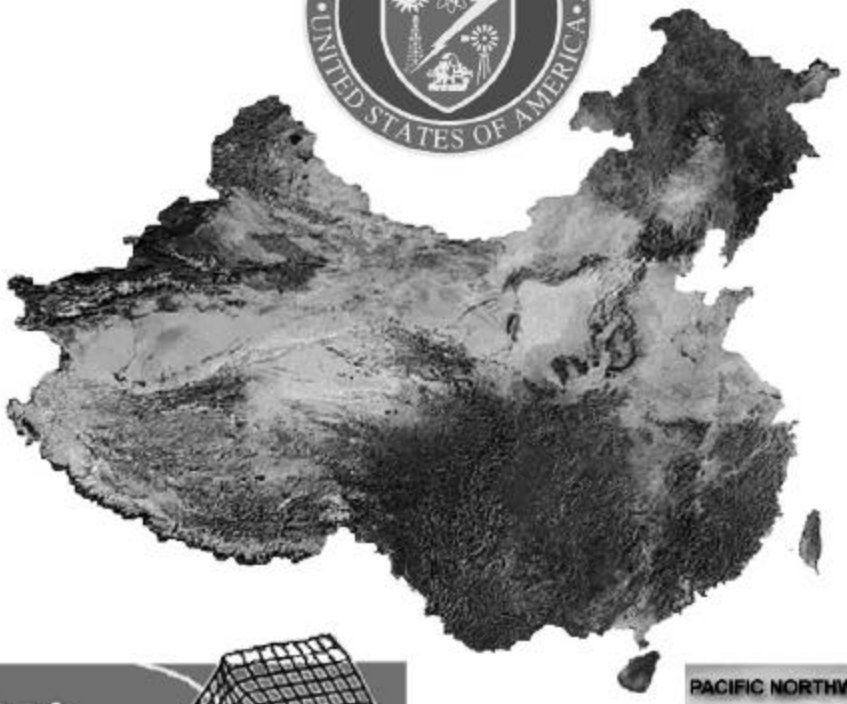
CHINA'S ENERGY

A FORECAST TO 2015



E. Iain McCreary
Alan Y. Gu
Verne W. Loose
Joseph M. Roop

U.S. DEPARTMENT OF ENERGY
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CHINA'S ENERGY

A Forecast to the Year 2015

Written Jointly by

Los Alamos National Laboratory
Project Lead, Supply Forecast, Classified Appendix
Author and Lead Researcher: E. Iain McCreary
Editor and Project Head: Verne W. Loose

and

Pacific Northwest National Laboratory
(Battelle Northwest)
Technical Support, Demand Forecast
Demand Section Author: Alan Y. Gu
PNNL Coordinator: Joseph M. Roop

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Point of Contact:
Los Alamos National Laboratory
Verne W. Loose
TSA-4 MS F604; *Energy & Environmental Analysis*
Los Alamos, NM 87545
(505) 665-5666 ph. (505) 665-5125 fax. loose@lanl.gov

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SCOPE NOTE

This project was sponsored by the U.S. Department of Energy's Office of Energy Intelligence, NN-30, as part of their energy security program. China looms as the single largest source of energy demand for the next two decades and as such, has the potential to adversely affect world energy markets and U.S. energy security through increased competition for available resources.

The work was conducted jointly by Los Alamos National Laboratory (LANL) and Pacific Northwest National Laboratory (PNNL). PNNL researched the energy consumption (demand) section and provided a computational model for the demand forecast, while Los Alamos was responsible for the sections on energy production (supply), Chinese national infrastructure, and integration of the report. Any errors discovered herein are the responsibility of Los Alamos National Laboratory.

As this report is an attempt to peer two decades into the future, it is perforce, speculative. Projections are based on recent historical trends which may be disrupted by dramatic changes in energy prices or catastrophic failure of any domestic Chinese energy industry, or a host of other unforeseen events. To hedge against this uncertainty, two scenarios are offered for both production and consumption. Each projection offers an expected, or "business as usual" scenario and a more optimistic "maximum" or "energy efficient" scenario.

Determination of the impact of Chinese petroleum imports on U.S. energy security was made by comparison of our import projections with other projections by the International Energy Agency (IEA), World Bank and several other international energy analysis groups. The unwavering consensus of all these agencies was that Chinese imports would not significantly affect world energy markets. The independent world energy price model which was to be supplied by PNNL to corroborate this conclusion was unavailable at the time this publication went to press.

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UNITS

bl	barrel
Bbl	billion barrels
toe	tons oil equivalency
Mtoe	million (x 10^6) tons oil equivalency
Btoe	billion (x 10^9) tons oil equivalency
tce	tons coal equivalency
Mtce	million (x 10^6) tons coal equivalency
Btce	billion (x 10^9) tons coal equivalency
W	watt
kW	kilowatt (x 10^3 watt)
MW	megawatt (x 10^6 watt)
GW	gigawatt (x10^9 watt)
Wh	watt hour
TWh	terrawatt (x10^{12} watt) hour
J	joule
GJ	gigajoule (x10^9 joule)
cal	calorie (heat)
m	meter
km	kilometer
p.a.	per annum (per year)

CONVERSIONS

Standard Coal:	1 ton	= 29.310 GJ	= 1.000 tce	= 5.14 bl oil	= 7.00 kcal
Chinese Average Coal	1 ton	= 20.943 GJ	= 0.714 tce	= 3.68 bl oil	= 5.00 kcal
Chinese Average Crude	1 ton	= 41.868 GJ	= 1.429 tce	= 7.35 bl oil	= 10.00 kcal
Chinese Average Crude	1 bl	= 5.694 GJ	= 0.199 tce	= 1.00 bl oil	= 1.36 kcal
Standard Natural Gas	10^3 m^3	= 37.68 GJ	= 1.29 tce	= 6.62 bl oil	= 9.00 kcal
Chinese Avg. Nat. Gas	10^3 m^3	= 38.98 GJ	= 1.33 tce	= 6.85 bl oil	= 9.31 kcal

Chinese Electrical Capacity Equivalency :	1 GW = 4.5 TWh
Coal to Oil Conversion:	1.0 tce = 0.7 toe
Oil to Coal Conversion:	1 toe = 1.429 tce
Oil to Oil Conversions:	1.0 toe = 7.19 bl oil *(IEA standard oil conversion rate)*

CHINA'S ENERGY

DESCRIPTION OF TERMS

In the following discussion of Chinese energy, the terms "consumption" and "production" are used rather than "supply" and "demand". Although similar, consumption and production are measures of physical quantities, and lack the economic data needed to calculate true "demand" or "supply".

Consumption refers to the actual energy used, or forecast to be used by the Chinese, measured in tons of energy resource. It is an incomplete reflection of energy demand, in that it perforce does not contain information about the price of the resource. In the Energy Consumption chapter (Section III) consumption is forecast in Mtoe, or million tons of oil equivalent. This is a measure of how much energy the Chinese would consume if all energy resources (coal, electricity, natural gas, etc.,) were assumed to be oil. The oil equivalency measure was chosen to allow easy comparison with other sources, including the International Energy Agency (IEA) and the World Bank, which both use oil equivalency as a standard unit.

Production is a measure of the total energy available, from all resources including coal, oil, natural gas, and electricity generation. It is an incomplete measure of supply, which like demand, is related to cost data. Because coal is the dominant Chinese energy resource (contributes 73% to consumption), and because most of the reference texts use coal as a measure of Chinese energy production, data is given in Mtce, or million tons of coal equivalent. This coal equivalency unit is used in both the Summary and Energy Production chapters (Sections I & II).

Conversion from oil to coal equivalents a simple matter of dividing the oil equivalency by 0.7 (see UNITS & CONVERSIONS, opposite).

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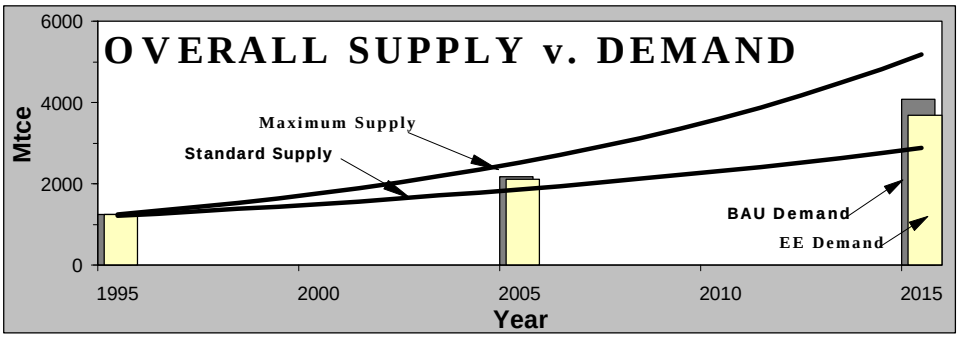
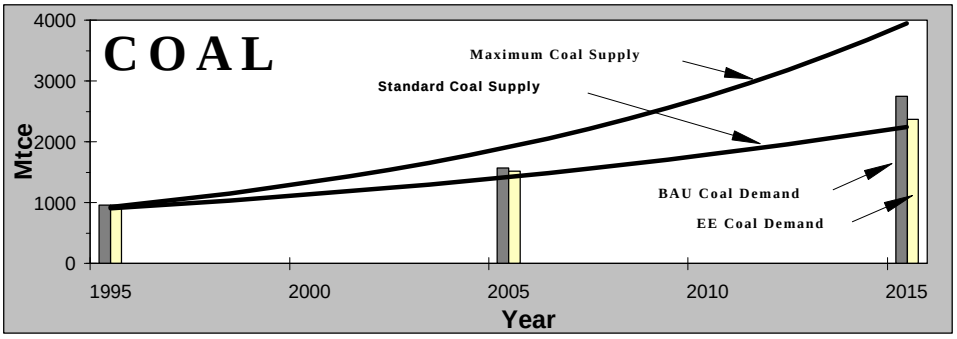
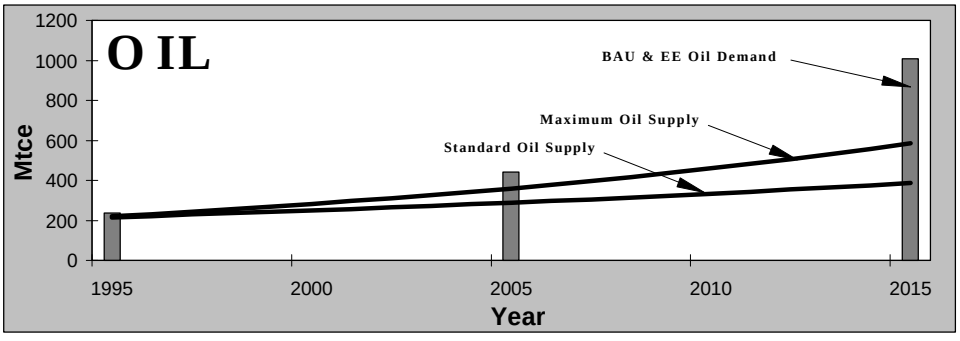
All plots have both domestic supply and demand data displayed. Supply data is represented by two curves, displaying the Maximum Scenario (best case) and Standard Scenario (expected) data. Demand data is displayed as bars for the years 1995, 2005 and 2015. The bars represent the Business As Usual (BAU) and Energy Efficient (EE) demand scenarios. For both supply and demand, actual energy production or consumption will fall between the two values.



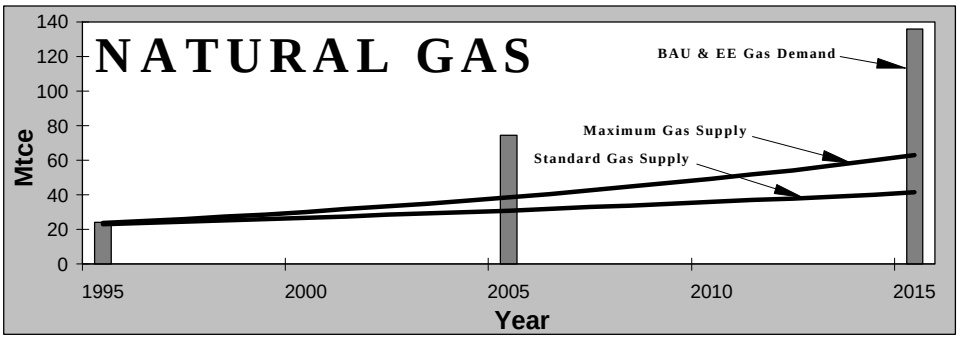
China can produce enough total energy resources for overall supply to meet demand, but fuel substitution and an increased dependence on coal will be required.



Coal can be extracted in excess of current demand trends, and will be used as a substitute for other fuels.



China faces major oil shortages of 5.9 to 8.8 million barrels per day by 2015



As residential demand drives demand for this resource, imports will continue.

CHINA'S ENERGY

KEY FINDINGS

GENERAL:

- Easy to consider China as "energy poor" despite a wealth of raw materials:
  - ⇨ Per capita energy consumption is one-sixth that of OECD countries.
  - ⇨ Energy consumption per dollar of GDP is ten times higher than OECD countries.
- Energy demand growing faster than supply.
- Major disconnects between available and required fuel types.
  - ⇨ Domestic energy supply is almost entirely coal, while urban consumers want clean household fuels like electricity and natural gas.
  - ⇨ Growth in industry and transportation have increased demand for oil and petroleum products, forcing China to become a net importer.
- Consumption centers far from resources.
  - ⇨ Transportation infrastructure critical to energy development.
  - ⇨ Rail freight capacity overloaded.

CONSUMPTION:

- Energy demand is expected to increase exponentially.
- Industry will continue to dominate consumption at 60% of total.
- Transportation fuels consumption will quadruple by 2015.
- Consumption in commercial buildings will increase seven fold by the year 2015.
- Demand for oil will force imports of up to 8.6 million barrels per day by 2015.

PRODUCTION:

- Coal will remain the dominant energy source.
- Oil and natural gas imports will increase dramatically. Oil imports will reach a maximum of 8.8 million barrels per day in 2015.
- China's proposed development of electrical power industry is financially achievable.
- Chinese domestic manufacturing capacity is insufficient to maintain growth. Between $4 to $8 billion in foreign equipment will be required annually through 2000.

US ENERGY SECURITY

- Even with China's increased petroleum imports, world energy markets will only grow at 2-3% per annum, and most of this growth will be from increased demand in the US and Europe.
- Chinese imports will not have a significant effect on energy markets, and therefore will not affect US energy security.

NOTES

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CHINA'S ENERGY

DOMESTIC ENERGY RESOURCES WILL BE ABLE TO MEET OVERALL DEMAND, BUT CHINA WILL NEED TO IMPORT OIL.

World's fastest growing economy

With Gross Domestic Product (GDP) growing at an average rate of 9.5% for the last fifteen years, China has the world's fastest growing economy. This rapid pace of growth and industrialization has caused economic strain, which is particularly noticeable in the inability of Chinese commercial fuel production to keep pace with demand. If China allows its commercial energy supply to fall much further behind demand, massive energy imports will be necessary in order to avoid severe bottlenecks in industrial production. Such an energy shortage could impact US energy markets, and possibly affect US energy security if China decides to balance the excess of demand over supply with imports. This paper reports the projection of Chinese commercial energy consumption, so that in conjunction with a production forecast, the likely energy resource shortfalls may be identified.

In terms of overall energy supply, China has the resources to meet rapid economic growth with only modest efficiency gains. However, there will be major disconnects between available and required fuels. Specifically, there will be severe shortages of petroleum and an over-abundance of coal.

Coal substituted for oil where possible

Should China adopt measures to encourage fuel substitution, the fuel imbalances force a dilemma. If imports are restricted to allow domestic prices to reflect the scarcity of oil, the ensuing market dislocations will hurt development; if imports are allowed, the cost will drastically reduce China's ability to finance badly needed energy infrastructure projects. However the energy supply problems are resolved, energy demand will continue to grow rapidly, led by the industrial sector.

ENERGY DEMAND

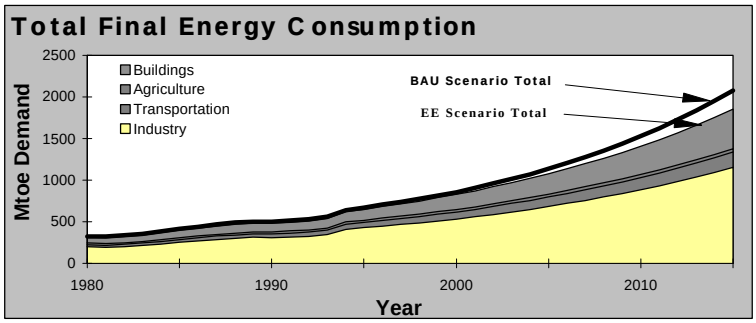
While China's energy consumption is only one-sixth that of OECD countries, population growth ensures significant pressure on energy demand. The combination of an expected population increase from 1.2 to 1.6 billion people by 2030, and rural-to-urban migration with increased living standards, will be accompanied by a shift in demand from coal and non-commercial

biomass fuels to cleaner household fuels like electricity and natural gas. Such consumption changes in the residential sector, accompanied by a similar shift away from coal to electricity and petroleum products in industry and increased demand for transportation fuels, have offset China's minor energy exports, and forced this country to become a net importer of oil and natural gas.

Energy demand will double by 2006, and redouble before 2015

Demand growth has been so rapid that total energy consumption more than doubled to 640 Mtoe in the fifteen years before 1994, and is expected to redouble by 2006; and redouble again to 2,077 Mtoe before 2015. Two growth scenarios were projected for this report, an expected growth model called the Business as Usual (BAU) scenario, and a more optimistic Energy Efficient (EE) scenario.

In the BAU projection, total final energy consumption reaches 2,077 Mtoe by 2015, while the EE projection reaches 1,880 Mtoe (2,967 Mtce or 14.9 Bbl oil, and 2,685 Mtce or 13.5 Bbl oil respectively).



INDUSTRY

Industry is largest energy consumer

Currently, industry contributes 55% to the total Chinese GDP and consumes 64% of the total final energy. In the past ten years, most of China's energy efficiency improvements have been in the industrial sector, so assuming that the sectoral GDP continues to grow faster than the national total, as it has for the past decade, the industrial sector will become an even larger part of the Chinese economy. However, the demand projection assumes that energy efficiency improvements will also continue, so that while industry will represent a larger segment of the economy, it will actually represent a smaller fraction of total final energy consumption, down to 60% from 64%. Despite this reduction, industry will remain the largest sectoral consumer at 1,240 Mtoe for the BAU scenario and 1,150 Mtoe for the EE scenario.

BUILDINGS (COMMERCIAL & RESIDENTIAL)

The buildings sector is a combination of the traditional residential and commercial sectors, representing the second largest sectoral energy consumer at 20% of the total final energy consumption, 113 Mtoe in 1993. Most of the commercial fuel consumption is split between electricity and petroleum products, while residential consumption is dominated by cooking and space heating fuels, specifically coal which accounts for 85% of residential consumption.

Residential demand for clean household fuels and electricity increasing

Fuel use in this sector is changing as urban consumers turn away from direct coal use, demanding both electricity and cleaner household fuels like liquefied petroleum gas (LPG). As new power grids are completed and rural consumers begin to buy electrical appliances, demand for electricity will skyrocket. In the urbanized southern coastal region, LPG demand has already forced China to become a net importer of this resource.

Energy consumption in the building's sector will increase by a multiple of 4.2, reaching 506 Mtoe in 2015.

TRANSPORTATION

Transportation consumption is small, but growing fast

China is unlike other countries because its transportation infrastructure is so limited that this sector, typically a major energy consumer in other economies, makes up less than 10% of the total final energy consumption. However, tremendous increases in road usage is expected to drive rapid growth of this sector.

Most consumption is by road transportation (65%), followed by rail (29%). Transportation energy consumption doubled between 1980 and 1993 to 56 Mtoe, and a quadrupling in the total number of motor vehicles to 12 million by the year 2000, will cause consumption to increased by 3 to 4 times the current value, from 60 Mtoe in 1994 to 259 Mtoe for the BAU and 187 Mtoe for the EE by 2015.

AGRICULTURE

Agriculture is the smallest energy consuming sector, at less than 5% of the total final energy. With labor intensive, low tech manual farming and only minimal mechanization, current consumption is mostly coal at 45%, followed by petroleum

products at 38% and electricity at 17%. As the larger farms are mechanized and the sector steps up production to meet the growing food demand, petroleum and electricity will contribute larger shares to the total, but the introduction of energy intensive western farming techniques is not anticipated except on the smallest of scales. Therefore, no significant changes are expected in agricultural demand, projected to reach 41 Mtoe in 2015 for both the BAU and EE scenarios.

ENERGY SUPPLY

Where the people are, energy resources aren't.

In terms of available energy resources, the problems China faces are not from extraction or development, but distribution. The Chinese population is concentrated on the eastern seaboard and in the southeast, while energy resources are everywhere but in those regions. Consequently, distribution infrastructure is critical to Chinese energy development. Transportation bottlenecks are already limiting energy resource shipments. Rail traffic is saturated, forcing the Chinese to abandon upwards of 20 million tons of coal to stockpiles annually. The lack of infrastructure is further inhibiting the development of new petroleum resources in remote western China. There is only one railway into the region, making delivery of both supplies and personnel difficult at best. Unless these infrastructure problems are resolved quickly, increases in resource production will be essentially meaningless because the Chinese will be unable to get the fuels to consumers.

COAL

Coal accounts for 73% of final energy consumption

Coal is the only resource the Chinese have available in abundance. The Chinese lead the world in coal production and this resource currently accounts for 73% of China's total primary energy consumption.

New railway development necessary

The geographic distribution of coal reserves is unfortunate in that 80% are in the northern provinces, while the population lives almost entirely in the south. With coal shipments saturating north-to-south rail traffic, and millions of additional tons of high grade northern coal abandoned to stockpiles annually for lack of transport, the majority of Chinese coal production is conducted in the south, producing undesireable and extremely low grade coal. Despite such limitations, coal remains the only commercial fuel available to offset the growing energy demand.

As the only resource which can be produced in any great quantity, the Chinese will substitute coal for other fuels wherever possible, and continue to build coal burning power plants for the

generation of electricity. This means that coal will continue to China's primary fuel source, dominating energy consumption.

OIL

Oil shortages up of 8.8 million barrels per day by 2015

The Chinese will face major oil shortages within the next decade. In ten years (2005) the Chinese will import between 1.2 million and 2.1 million barrels a day depending on domestic production rates. By 2015, the domestic shortfall will have reached 5.8 million to 8.6 million barrels a day.

Production capacity of new oil fields unproven.

Domestic oil production has stagnated in the past decade. The major fields in north-east China have seen zero percent growth since 1985 despite the continuous addition of new wells. Recently, the Chinese have begun to develop potential oil resources in the western desert, specifically a basin the size of France called Tarim. However, despite Chinese optimism and propaganda, the production potential of the region is unproven. This year Tarim will more than double its petroleum output, but still contribute less than 3% to the national petroleum production total. Even China's minuscule offshore industry will produce almost double the Tarim amount.

NATURAL GAS

Natural gas passed over in favor of oil development.

The Chinese have always, and will continue to favor oil over natural gas development. Less than 3% of their potential gas resources have been proven, and development of the proven resources has been slow. In 1990 the Chinese claimed that they would increase natural gas production by 292% before the year 2000. This will not happen. The 1994 production rate was only 9% greater than in 1990. Although gas would seem an ideal residential fuel source, especially in cities, development is simply too expensive. The Chinese will continue to develop oil resources first, and use readily available domestic coal as an alternative to natural gas imports.

HYDROPOWER

China has the largest hydropower generating potential in the world. Steep runoffs from the Himalayan plateau, combined with heavy rainfall in central China, generate many large, fast flowing rivers and literally thousands of smaller ones. China has more than 150,000 small scale rural hydro plants in operation, most with capacities less than 500 kW (capable of powering fewer that 250 houses with four light bulbs and one refrigerator each).

Hydropower resource unable to replace coal fired power plants

Although frequently hailed as a cure-all for the problems China faces in electrical power generation, hydropower is no panacea. Even if all exploitable resources were fully used, hydropower could only contribute 379 GW. This is only less than one third of the projected capacity for the year 2015. Further, most of this generation capacity comes from small sites unsuitable for industrial, or even urban use. Thus, hydropower will likely continue to be the electricity source of choice in rural China, but it will never replace coal burning thermal plants.

NUCLEAR

Nuclear power will never be a major energy source.

Currently, China has only two online nuclear power plants. Both are pressurized water reactors (PWRs). The 300 MW Quinshan plant, designed and built by the Chinese, supplies power to Shanghai. While a French built PWR with two 900 MW reactors in south China's Daya Bay supplies power to Hong Kong. Although the Chinese have discussed a variety of other nuclear projects, only two plants are actually in the works. One will provide power to the north eastern industrial and shipping region on the Bo Hai Sea, while the second will sit across Daya Bay from the existing plant and supply power to southern China. Between upgrades and the two new plants, China's nuclear capacity will rise to 8.7 GW by 2010; more than quadrupling the current nuclear capacity, but still contributing less than 2% to the total electrical generating capacity.

There are more than ten additional nuclear plants in various stages of proposal, from feasibility studies to conjecture. However, there are serious doubts as to China's ability to supply fuel for such a large number of plants.

RENEWABLE RESOURCES

There are regions with abundant solar, geothermal and wind energy resources, but all are remote. China's sunny regions are in the far western Himalayan plateau, while populated central China is perpetually cloud covered. The geothermal resources, mostly hot springs, are also in the Himalayas, with a few others scattered along the southern coast. China's windiest areas are in the western desert and remote northern China along Inner Mongolia. Currently, all these resources combined contribute less than half of one percent to China's energy consumption. It is highly unlikely that this fraction will change in the foreseeable future.

CHINA'S ABILITY TO GENERATE ELECTRICITY

China faces a maximum 24 GW shortfall in annual turbine production

China needs to purchase several billion dollars worth of foreign equipment to meet its stated electricity generation goals. Published State plans show that China intends to add 101 GW generating capacity between 1995 and 2000, or 17 GW added annually. Such development would put the total capacity at 300 GW in the year 2000, but the Chinese can only manufacture 9 GW in turbines domestically per year, leaving a shortfall of 40 GW.

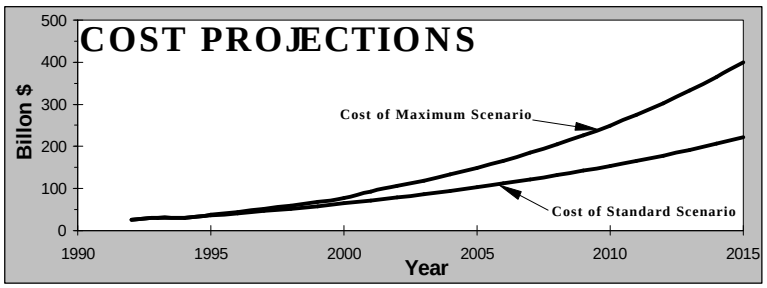
If all other potential domestic manufacturers are included, annual turbine production climbs to 12 GW, still 5 GW short of the requirement. Complicating the situation, the 17 GW annual requirement does not consider refits or upgrades, which if included send the annual capacity requirement up to a maximum of 36.6 GW. To make up this difference China would need to purchase up to 24 GW capacity in foreign generating equipment annually.

China will spend $4 to $8 billion annually on foreign equipment through the year 2000.

In past years, China has bought up to 20% of its generating capacity from foreign suppliers. So while a precedent exists, the scale required makes full refits an unlikely outcome. A more realistic option is that the Chinese will purchase between 5 and 10 GW in foreign equipment for new generating capacity and forego much of the upgrades and refits. This would limit growth, but have the benefit of costing only $4 to $8 billion annually, as opposed to the maximum amount of $19 billion annually to make full refits with foreign equipment.

COST OF CHINESE ENERGY DEVELOPMENT

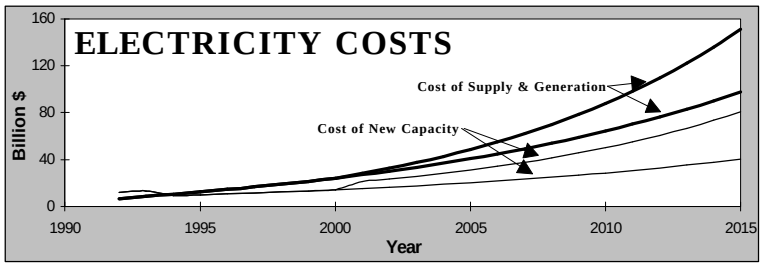
Total energy expenses in 1995 for extraction of coal, oil and natural gas were $13.5 billion, with an additional $12.5 billion spent on electricity generation and $10 billion spent on the installation of new generation capacity. These costs represent a total of $36 billion, or 5.6% of the $643 billion Chinese GDP in 1995.



Chinese spent $36 billion on energy projects in 1995, about 6% of GDP

The costs of the Standard Supply Scenario represent a similar fraction of the Chinese GDP, with values of 6.1% in 2000 and 6.4% in 2015, while the maximum scenario has higher associated costs, representing a 6.9% GDP fraction in the year 2000 and a very high 11% fraction in 2015.

This indicates that the Standard Supply Scenario is a reasonable projection of Chinese energy development, because as a fraction of total spending, the costs are very close to what the Chinese have spent in the past. The ceiling estimate offered by the maximum scenario is less likely, for although the Chinese may have single years of growth at the Maximum scenario rates, they simply cannot afford the cost of sustained development at such a high rate.



US ENERGY SECURITY

Increased Chinese oil imports will have little effect on world energy markets and will not affect US Energy security.

Only one energy resource is likely to have any impact on US energy security: oil. The Chinese petroleum shortage will necessitate increasing import volumes, up from the current (1994) volume of 60 thousand barrels per day, to between 1.2 million to 2.1 million barrels per day by the year 2005, and 5.8 to 8.6 million barrels per day by the year 2015 depending on the rate of domestic resource development.

Although it is possible that Chinese imports might effect US energy security by disrupting the petroleum supply, it is unlikely. As large as these volumes are compared to China's historical import volumes, they are not large enough to destabilize

international oil markets. China's imports are minor compared to the anticipated increases in consumption in the US and Europe. All told, petroleum demand on the world energy market will grow by just 2-3% annually [Clawson]. It is the consensus among analysts that China's growing imports will not disrupt the international flow of oil, and therefore will not impact US energy security.

CONCLUSIONS

As demand for fuel grows, China will continue to import oil and natural gas.

China will continue to import oil and natural gas, and spend increasing amounts on foreign electrical generation equipment. Domestically, the Chinese face major problems with the lack of support infrastructure needed for continued development of energy resources, especially in increased freight handling capacity. If resource production rates are to increase, these infrastructure bottlenecks must be resolved, else the lack of distribution will, for all intents, cripple the energy industry.

Demand for fuels and electricity will grow in all sectors. Improvements in consumption efficiency will reduce demand from existing consumers, but will not compensate for the demand increases as standards of living rise and the industrial sector continues to grow.

China's oil and natural gas shortages may be partially alleviated by use of fuel substitution in the industrial and residential sectors, especially as electrical tools and appliances become more common. If coal can be domestically substituted as a fuel on a wide basis, and the remainder exported, China can remain energy self sufficient despite the imports of oil and natural gas.

The certainty of increased coal consumption raises a host of environmental concerns, including the likelihood of sulfur related atmospheric contamination in North America from Chinese emissions. However, since the Chinese have no alternative but to continue utilizing coal as their major energy resource, concerned western countries must convince the Chinese to step up domestic pollution control measures.